AlliedSignal Ceramic Components Cost Effective Ceramics

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Development of a Production-Viable Manufacturing Process for AS800 Silicon Nitride Components

Allison Engine Company Contract DEN3-336
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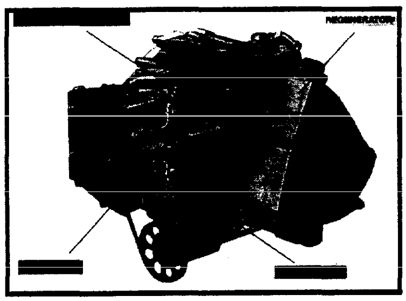
Objectives:

- Cost-Effective Production Process for the Allison Hybrid Vehicle Turbine Engine-Technology Support (HVTE-TS) Program
- Deliver Engine Hardware
  - Turbine Rotor
  - Thin-Walled Combustor

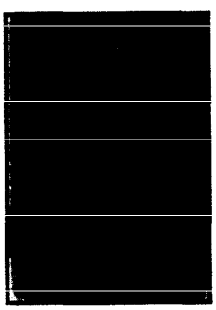


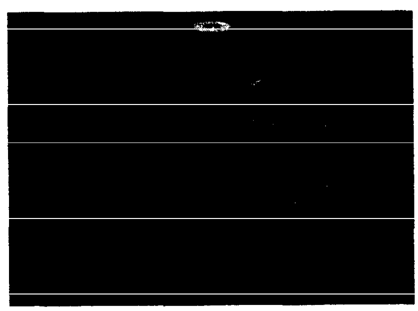
Approach:

- Near-Net Shape Process
- Permanent Molds
- Gelcast AS800 In-Situ Reinforced Si_3N_4

Accomplishments:

- Molds Fabricated, Gelcasting Parameters Established
- Turbine Rotor Machining Development Underway
- Combustor Machining Developed
- Combustors Delivered to Allison





Future Direction:

- Deliver Turbine Rotors for Test
- Develop Improved Combustor Mold Core Technology

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In-Situ Toughened Si_3N_4

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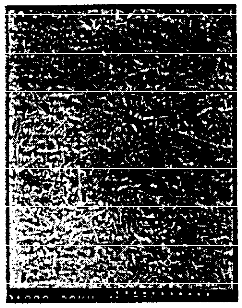
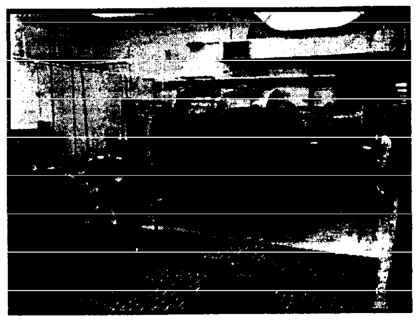
Objectives:

- Improve Properties and Processing of an In-Situ Toughened Silicon Nitride for Heat Engine Applications



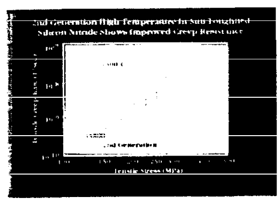
Approach:

- Improved Properties and Processing of Lab Scale Material Through Composition and Process Optimization
- Optimize Material to Production Scale
- Demonstrate Component Fabrication Capability
- Establish Expanded Database
- Develop 2nd Generation Material with Higher Temperature Capability to Meet Future Heat Engine Needs

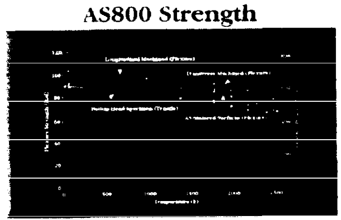


Accomplishments:

- Material Properties Meet Heat Engine Requirements
- Fabrication Process Scaled Up to Production Scale
- Engine Component Fabrication Demonstrated
- Expanded Database, Including Tensile Properties
- Production Material Under Evaluation by Users: GE/EPRI, AlliedSignal, Solar Turbines, Allison Engines, Teledyne
- Second Generation Material being Optimized

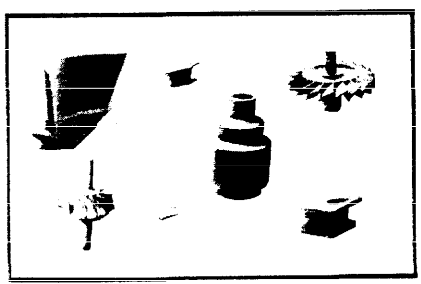


AS800 Strength



Future Direction:

- Complete Production Material Database
- Demonstrate Improved Properties of 2nd Generation Material Made by Production Process
- Optimize Gelcasting of AS800 to meet PNGV Thin Wall Component Requirements, e.g. Combustors, Scrolls, etc.



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Ceramic Nozzle Production Demonstration Program

Subcontract to AlliedSignal Engines

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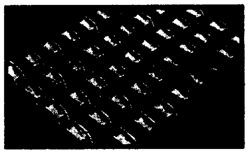
Objectives:

- Scale Up Process for Manufacturing Silicon Nitride Parts to 500/Month Capacity
- Demonstrate 100/Month Production Capability on Turbine Nozzles
- Demonstrate Process Control, Improved Yield and Decreased Cost
- Deliver Turbine Nozzles and Blades to AlliedSignal Engines for Engine Demonstration

Approach/Accomplishments:

Scale-Up and Production Demonstration

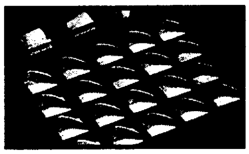
Production Sequence



331-200 Turbine Nozzles

Model 331-200 Turbine

- Slip Cast Nozzle Blank
  - 150 Piece Lot Size
  - AS800 Material
- Bisque Machine Nozzle Shape
  - Versatile
  - Current Yield > 85%
- Gas Pressure Sinter
  - Furnace Capacity > 300 Parts
- Final Machine Engine Attachments



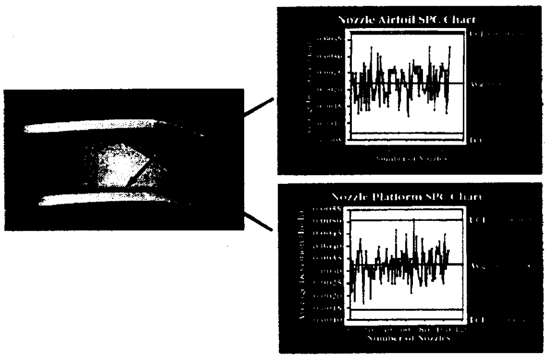
331-200 Turbine Blades

- > 450 Hours of Successful Turbine Engine Testing on AS800 Nozzles
- AS800 Turbine Blades Proof Tested in Preparation for Engine Test

Process Control

Key Characteristics	Process in Control
Slip Viscosity	✓
Presintered Density	✓
Presinter Machined Dimensions	✓
Densified Dimensions	✓
Final Machined Dimensions	*
Mechanical Properties	✓

*SPC Data Being Obtained



Improved Yields and Cost

1993 Baseline Yield = 25%   Current Estimated Yield = 67%

Process Step	1996 Yield	Process Step	1996 Yield	Process Step	1996 Yield
Casting	99%	Presinter Machining	87%	Final Machining	96%*
Drying	100%	Densification	98%	Inspection	82%*
Presintering	100%				

* Estimated

Future Direction:

- Complete Production Demonstration of 100 Nozzles/Month
- Compile Final SPC, Yield and Cost Data
- Continue Delivery of Turbine Nozzles and Blades for Engine Endurance Testing

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Cost Modeling Analysis of Fabrication Approaches for Silicon Nitride Components

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Objectives:

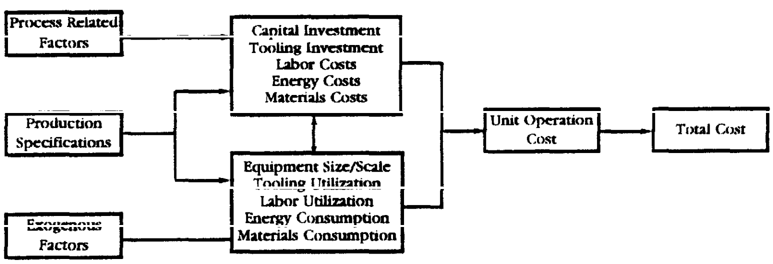
- Develop a Cost Model to Evaluate Competing Diesel Engine and Turbomachinery Ceramic Component Fabrication Methods
- Determine Relative Benefit/Trade-Offs of Near-Net-Shape Forming Methods vs Machining of Billets
- Analyze and Determine the Potential Low-Cost Forming Method for Specific Components and Component Families
- Identify Aspects of the Manufacturing Process that are Cost-Controlling

Approach:

Components Studied:

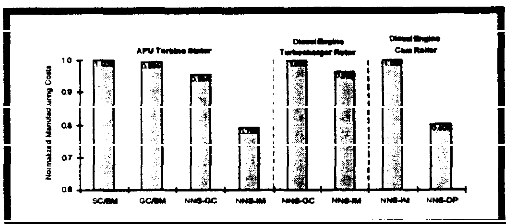
- Diesel Engine Cam Roller Follower - 500,000 units/yr
- Diesel Engine Turbocharger Rotor - 50,000 units/yr
- Auxiliary Power Unit Turbine Stator - 5,000 units/yr
- Fabrication Processes Include Slip Casting (SC), Gelcasting (GC), Injection Molding (IM), Dry Pressing (DP), Employing Near Net Shaping (NNS) or Billet Bisque Machining (BM)

Technical Process Cost Model Methodology



Accomplishments:

Preliminary Cost Analysis Results for Various Fabrication Techniques for Target Components



- Near Net Shape Forming Techniques Show Cost Advantages Over Bisque Machining of Billet Stock
- Yield Improvements and Process Equipment/Manpower Scaling Result in Large Reductions in Manufacturing Costs
- Major Contributors to Manufacturing Cost Include Direct Labor, Materials, Equipment, Cost of Capital

Future Direction:

- Continue Analysis of Target Components, Refining Model Inputs to Realistic Production Values
- Modify the Model to Allow Analysis of a Wider Range of Components
- Complete Validation of the Model